Ad Hoc Networks 41 (2016) 15–29

Contents lists available at ScienceDirect

Ad Hoc Networks

journal homepage: www.elsevier.com/locate/adhoc

Trust based reliable transmissions strategies for smart home energy consumption management in cognitive radio based smart grid

Uthpala Subodhani Premarathne[a,b,*], Ibrahim Khalil[a], Mohammed Atiquzzaman[c]

[a] National ICT Australia (NICTA), RMIT University, School of Computer Science and IT, Melbourne VIC 3001, Australia
[b] Department of Computational Mathematics, Faculty of IT, University of Moratuwa, Katubedda, Sri Lanka
[c] School of Computer Science, University of Oklahoma, Norman, OK 73019-6151, United States

ARTICLE INFO

Article history:
Received 16 June 2015
Revised 3 December 2015
Accepted 12 December 2015
Available online 12 January 2016

Keywords:
Cognitive radio network
Smart home
Smart grid
Spectrum sensing
Cooperative spectrum sensing
Energy management

ABSTRACT

Reliability of smart home energy management (SHEM) is enhanced due to the use of opportunistic cognitive radio based communications for reliable transmission of peak period energy utility data. Cognitive radio networks are apt communication solutions capable of offering reliable opportunistic data transmissions through spectrum reuse. Reliable opportunistic data transmissions ensure strategic decision making and to execute critical control operations for sustainable energy utilizations. Accurate spectrum sensing and efficient spectrum sharing are vital to aspects of reliable peak energy consumption data transmission. Cooperative spectrum sensing has been proposed as a more reliable method for gaining accurate spectrum availability detection. Trustworthiness of the local decisions of cooperating users is vital for the accuracy of the final spectrum availability decision. However, measures which can assess the trustworthiness of cooperating users are given less attention. In this paper, we describe a novel multi-attribute trust based framework to facilitate reliable spectrum sensing and priority based spectrum access allocation to enhance delay sensitive data transmissions. We have evaluated our solutions using extensive simulation experiments. Furthermore, we comparatively analyzed the reliability of the proposed user selection method for known spectrum sensing data falsification (SSDF) attack behaviors to accurately identify the non-malicious users. As evidenced by the results proposed novel multi-attribute trust based transmission strategies offer greater reliability in ensuring timely availability of peak period energy utility data for SHEM.

1. Introduction

Smart homes transparently unifies various home appliances, smart sensors and wireless communication technologies for efficient energy utilization management through smart grid. Smart home energy management (SHEM) aims to make sustainable energy flow management based on energy utility data. Peak period energy utilization is more significant in making sound decisions on energy consumption in a smart home as well for demand management in smart grid. In addition, peak period energy utility tracking can help to reduce additional costs and also to apply appropriate controls to manage the energy flows in smart homes.

* Corresponding author at: Department of Computational Mathematics, Faculty of IT, University of Moratuwa, Katubedda, Sri Lanka. Tel.: +94 771762887.
E-mail addresses: uthpalasubodhani.premarathne@rmit.edu.au, s3308412@student.rmit.edu.au, uthpalas@uom.lk (U.S. Premarathne), ibrahim.khalil@rmit.edu.au (I. Khalil), atiq@ou.edu (M. Atiquzzaman).

http://dx.doi.org/10.1016/j.adhoc.2015.12.004
1570-8705/

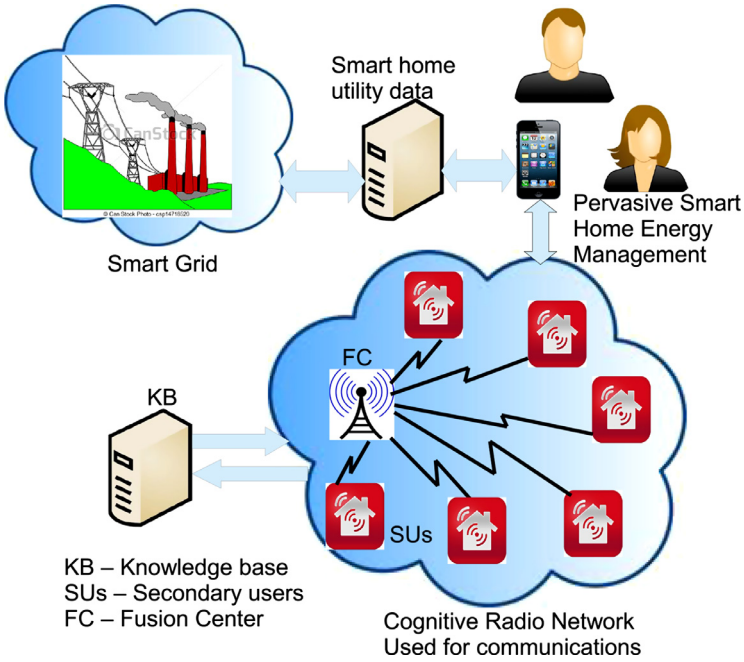

Fig. 1. Cognitive radio based Smart Home Energy Management (SHEM) – smart home users remotely manage energy utilizations over cognitive radio communications. Reliability of the peak period energy utility data transmission is facilitated by opportunistically transmitting over available spectrum. Therefore, reliability of SHEM relies heavily on the accurate detection of available spectrum.

Smart meters are the main energy consumption data relaying entity in smart grid [1] (see Fig. 1). It is expected by 2015 there will be over 65 million smart meters installed int he United States and world wide deployment is increasing sharply [3]. Therefore, large number of users utilizing limited dedicated wireless channels for utility data transmissions can cause serious spectrum congestion. To avoid delays and interruptions for energy utility data transmissions more spectrum allocations or efficient spectrum utilization methods are necessary. A pragmatic solution is to use opportunistic data transmissions over cognitive radio communication networks. Smart meters can be designed to transmit meter data either on the original unlicensed channel or the additional licensed channel, in order to improve reliability and reduce delays [2].

Usefulness of cognitive radio communications can be emphasized based on two main requirements of SHEM.

- SHEM need to utilize demand based energy consumption data during peak periods for effective and sustainable energy utility management. Therefore, timely availability of data is vital. Efficient spectrum reutilizations can significantly contribute to timely data transmissions for SHEM applications [4].
- To ensure minimum interference levels among different frequencies being used in smart homes, it is more desirable to accommodate data transmissions over idle channels or spectrum holes when allocated channels are congested or unavailable due to significant fading or shadowing conditions [5–10]. Therefore, cognitive radio networks are apt communication solutions for SHEM.

Opportunistic cognitive radio communications are necessary to ensure reliable peak period energy utilization data transmissions in smart homes. In cognitive radio networks, absence of primary user (PU) provides opportunities for the secondary users (SU) to transmit over the vacant spectrum [11]. Inability to detect available spectrum will hinder the expected opportunistic delay-sensitive data transmissions for when there is congestion in dedicated channels [4].

Inaccurate spectrum availability detection can result due to unfavorable channel conditions (e.g. fading, shadowing) as well as due to malicious attacks, such as spectrum sensing data falsification attacks [12–14] and denial of service attacks [13]. The objectives of these attacks are (i) to declare channel as vacant when actually the PU is transmitting and (ii) to declare the channel as occupied when in fact the PU is not transmitting [13]. In denial of service attacks the SUs are not given sufficient time for spectrum sensing and to communicate the local spectrum sensing decisions among the other SUs. Among different sensing approaches, cooperative spectrum sensing strategies have been proposed to increase the accuracy of spectrum sensing [15,16].

1.1. Limitations of existing solutions

In the recent past cognitive radio communications have been proposed for smart grid [1,10,17–19]. The obvious advantages of opportunistic communications with less interferences with other operating frequencies of different components makes cognitive communications suitable for smart grid. Opportunistic data transmissions between the advanced metering infrastructure (or smart meters)